DOLOMITIC GLADES OF EAST-CENTRAL MISSOURI

RALPH O. ERICKSON
University Fellow, Henry Shaw School of Botany of Washington University
LOUIS G. BRENNER
Formerly Graduate Apprentice, Henry Shaw School of Botany of Washington University
AND JOSEPH WRAIGHT
Formerly Assistant in Geography, Washington University

A characteristic feature of the landscape of the Ozarks is the occurrence on south- and west-facing hillsides of barrens which are locally known as "glades" or "cedar glades." Such glades, occurring on outcrops of thin-bedded dolomite or dolomitic limestone, principally of lower Ordovician age, have been studied in the area shown on the map (fig. 1). It includes about three-fourths of Jefferson County and small parts of adjacent Franklin, Washington and Ste. Genevieve Counties, Missouri, and lies from 25 to 50 miles west, southwest and south of the city of St. Louis, on the northeastern border of the Ozark Plateau.

The unique character of the Ozark glades has long been recognized by botanists, though no extended accounts have been published. Discussions may be found in the papers on the Ozark flora by Palmer ('21) and by Steyermark ('34; '40), who consider them as relics of the former plains flora of the region. References to the glades may also be found in the geological and geographical literature (e. g., Weller and St. Clair, '28; Pike, '28; Sauer, '20; Cozzens, '37; '39).

The present study is largely a by-product of two other investigations, by Brenner and by Erickson. Brenner's interest in the glades grew out of his study of the environmental variables at the Gray Summit Arboretum of the Missouri Botanical Garden (Brenner, '42). Erickson is engaged in a study of the distribution of *Clematis Fremontii* in Missouri, and the detailed mapping of the glades was done primarily as preliminary work for that study. Wraight became interested in the problem for its geographical and ecological implications. The analysis of the physical characteristics of the glades which follows is largely due to the field work of Brenner and Wraight.

This paper is primarily descriptive, but an attempt has also been made to analyze the factors which are responsible for the occur-

rence of the glades and for their characteristic physical conditions. Although a detailed treatment of the flora is beyond the scope of the present paper, the following remarks may be made. The glades are sometimes completely treeless, but more often there are "islands" of small trees surrounding gullies or ledges of rock. The species most frequently found are:[1] *Juniperus virginiana, Quercus Muhlenbergii, Q. stellata, Celtis pumila, C. pumila* var. *georgiana, Acer saccharum* var. *Schneckii, Rhamnus caroliniana, Vitis Lincecumii* var. *glauca, Cornus florida* and *Bumelia lanuginosa.*

Most characteristic of the glades, however, are the herbaceous species. A partial list includes: *Andropogon provincialis, A. scoparius, Panicum virgatum, Sporobolus heterolepis, Bouteloua curtipendula, Allium stellatum, Nothoscordum bivalve, Agave virginica, Arenaria patula, Clematis Fremontii, Draba cuneifolia, Leavenworthia uniflora, Baptisia vespertina, Psoralea esculenta, Petalostemum purpureum, Croton capitatus, Euphorbia corollata, Viola pedata, Oenothera missouriensis, Polytaenia Nuttallii, Asclepiodora viridis, Acerates viridiflora, Heliotropium tenellum, Scutellaria parvula, Houstonia angustifolia, Solidago Gattingeri, Aster oblongifolius, Silphium laciniatum, S. terebinthinaceum, Rudbeckia missouriensis, Echinacea pallida* and *Coreopsis lanceolata.*

Although the grass cover of the glades is rather sparse, usually consisting largely of separated clumps of *Andropogon,* the grass is the most conspicuous of the herbaceous plants (fig. 4). Despite the grassy appearance of the glades during most of the year, there are a number of other plants which, during their blooming periods, cover the glades with solid masses of flowers. Such plants include both annuals like *Leavenworthia uniflora,* which flowers in April, and perennials such as *Rudbeckia missouriensis,* which carpets the glades in late July and early August. The glade species are all more or less xerophytic, and a number of them are remarkable for their linear or finely divided leaves.

In mapping the glades, use was made of the aerial photographs on file at the offices of the county Agricultural Conservation Associations. The photographs were taken at an altitude of about 13,000 feet and are printed to a scale of 8 inches to a mile. Most of them

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[1] The list of species given here agrees with Palmer and Steyermark's ('35) catalogue, although the authors realize that, in some instances, that work is not up-to-date in nomenclature.

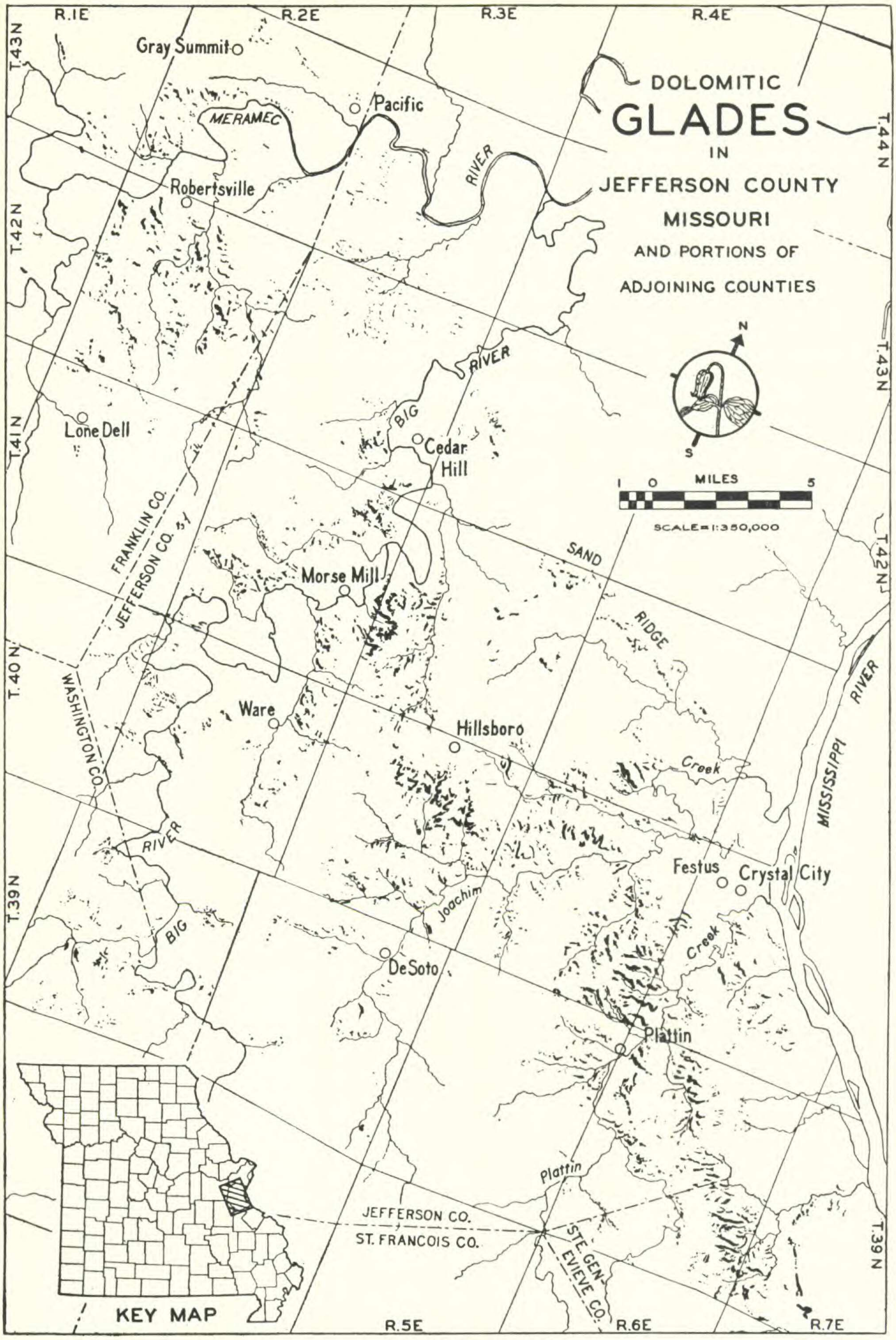
R.1E
R.2E
R.3E
R.4E
T.43N
T.42N
T.41N
T.40N
T.39N
T.44N
DOLOMITIC
GLADES
IN
JEFFERSON COUNTY
MISSOURI
AND PORTIONS OF
ADJOINING COUNTIES
Gray Summit
Pacific
MERAMEC
RIVER
Robertsville
BIG
RIVER
Lone Dell
Cedar
Hill
FRANKLIN CO.
JEFFERSON CO.
Morse Mill
SAND
RIDGE
Ware
Hillsboro
Creek
RIVER
WASHINGTON CO.
MISSISSIPPI
RIVER
Festus
Crystal City
Joachim
Creek
BIG
DeSoto
Plattin
Plattin
JEFFERSON CO.
ST. FRANCOIS CO.
STE. GEN-
EVIEVE CO.
N
S
1 0 MILES 5
SCALE=1:350,000
KEY MAP
R.5E
R.6E
R.7E

FIGURE 1

were taken in September, 1937. Glades can be recognized rather easily on the photographs by their whiteness, and they can be distinguished from other white areas, such as bottomland pasture, by their characteristic outline, by the islands of red cedar which occur in most of them, and, in the larger glades, by ledges of resistant rock which give the appearance of contour lines. For each square mile within the area, a tracing was made showing the outlines of glades and some other features such as roads and creeks. The map (fig. 1) was drawn from the photo tracings on a base taken from the county highway maps published by the Missouri State Highway Department. All the glades were drawn as accurately to scale as possible. The drainage was drawn in from the photo tracings and the topographic maps of the U. S. Geological Survey. The map has been checked by field work to some extent throughout the area and rather completely in a few places. The errors are confined to the smallest glades, since it is somewhat difficult to make a distinction between very small glades and hillsides with a rather open cover of red cedars.

The glades in this region almost invariably occur on south- and west-facing slopes. They rarely extend over the top of a hill or ridge and are never found in a valley bottom. The soil mantle is extremely thin, very often less than one inch deep, and there are always numerous flat fragments of the bed rock strewn on the surface (fig. 4). The ground-water relations of the glades are characteristic. During late autumn, winter and spring they are typically so saturated that there is almost continual seepage, and such plants as *Nostoc terrestris* and *Isoetes Butleri,* members of normally aquatic genera, flourish. This saturation leads to a great deal of disturbance from frost heavage when the ground thaws in the spring. During the summer months, on the other hand, the glades are extremely xeric, and for a period in the middle of the summer very little green may appear.

The conditions determining the topographic position of the glades, their unusual physical characteristics and their peculiar flora represent a rather complex interplay of factors such as angle of slope, thin soil mantle, attitude to the sun's rays, and meteorological conditions, as well as the composition and physical characteristics of the underlying rock.

The geological relations of the glades are quite evident from a study of their distribution. Formations of upper Cambrian and

middle and lower Ordovician age outcrop within the area of this study, the geological column being as follows:[2]

Ordovician	Mohawkian	Kimmswick	Included within the glade area of this paper
		Decorah	
		Plattin	
	Big Buffalo	.....	
		Joachim	
		St. Peter	
		Everton	
	Canadian	Powell	
		Cotter	
		Jefferson City	
		Roubidoux	
	.....	Gasconade	
		.....	
Cambrian	Ozarkian	Eminence	
		Potosi	
		Derby-Doerun	
		.....	
		Davis	
		Bonneterre	

These formations present some lithologic contrasts, including a variety of sandstones, limestones, shales and dolomites. The dolomites are of particular importance, since the presence of thin-bedded, relatively non-cherty dolomite (fig. 5) appears to be the decisive factor in the production of glades. The largest glades occur on the outcrop belt of the lower part of the Powell formation, which includes the greatest thickness of such rock in the column. Similar dolomitic strata are found in the Joachim formation, the upper portion of the Everton, the Cotter, the Jefferson City and perhaps in all the other formations listed above except the St. Peter sandstone, the Roubidoux formation and those formations above the Joachim. The largest and most numerous glades, as stated above, occur on outcrops of the lower Powell.[3] The Cotter and Jef-

[2] The geological column is reproduced from the Geological Map of Missouri, with the omission of formations absent from the area of this study.

[3] The formations of the Canadian Series are notoriously difficult to distinguish in the field. They vary greatly in lithology within short distances, both vertically and horizontally, and fossils are difficult to find. The geological correlations of the glades made in this paper are based upon the geological map accompanying Pike's ('28) dissertation on the Crystal City quadrangle, which agrees in interpretation with the map of Ste. Genevieve County of Weller and St. Clair ('28); on personal conversation with Mr. James S. Cullison; and on such field identification by the authors as was possible.

Cozzens ('37; '39) has correlated the glades with the Cotter formation. While the Powell is the most important glade-producer in the southern part of the area described

ferson City, which, with the Powell, constitute the Jefferson City group of the state geological map, are next in importance as glade-producing formations. Small glades are found frequently on the Joachim; the location of the St. Peter-Joachim escarpment (Sand Ridge) is indicated in fig. 1 by the glades on this formation. The Everton is of slight importance in this study. The Gasconade, Eminence and Potosi formations are not important, but small glades apparently occur occasionally. The numerous small glades in northeastern Washington County (T.39N, R.3E) are found on the Derby-Doerun. Glades are reported to occur on the Bonneterre formation (Sauer, '28, pl. III a), but its outcrop lies outside of the area investigated.

In the area of the Plattin and Kimmswick outcrops, south-facing slopes have a sparse tree cover in which red cedars often predominate, and in some places there are few, if any, trees. However, such slopes in the Plattin and Kimmswick country are much steeper than in the area of this study, and there is no thin-bedded dolomite. Where the hillsides are barren enough to justify the term glade, the appearance is quite different both floristically and lithologically from the dolomitic glades. Glades occur on the St. Peter sandstone which also support a different flora from that of the dolomitic glades.

Besides the lithologic character of the rocks, a second factor determining the areal distribution of glades is the amount of local relief. The glades lie almost wholly within the Mississippi and Missouri River Border Provinces defined by Sauer ('20, fig. 18), which are equivalent to the River Border Region of Cozzens ('39, fig. 4). The region as a whole is one of moderate relief for the Ozarks, values of 300 to 400 feet being given by Cozzens, but there is, of course, considerable variation within the region. Glades seem to occur only where the proper lithologic conditions are found in conjunction with relatively high local relief. For instance, reference to the map will show that there are practically no glades between Hillsboro and Sand Ridge. This area is underlain by the same thin-bedded dolomite which elsewhere produces glades, but the relief is not sufficient to allow their development here. In the southeastern part of T.40N, R.5E, one to three miles north of the

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here, the only part for which a large-scale geological map is available, the glades are by no means limited to the Powell. Considering the variability of the Jefferson City group from place to place, the Cotter formation may very well be the most important glade-former elsewhere.

Fig. 2. Glade on lower part of the Powell formation, one mile north of Plattin (SE ¼, S. 36, T. 40N, R. 5E). All the photographs were taken in January, 1942.

Fig. 3. Severely grazed glade, 2½ miles southeast of Hillsboro (NE ¼, S. 14, T. 40N, R. 4E).

Fig. 4. Portion of the glade shown in fig. 2.

Fig. 5. Recent road cut near Hillsboro, showing thin-bedded dolomite of the kind on which glades occur.

village of Plattin, on the other hand, where rock of the same lithology underlies land dissected by tributaries of Plattin Creek, glades occur on every ridge.

Much of the rock scattered on the surface of the glades is soft and friable, and is called "cotton rock" by residents of the Ozarks. Samples from several localities were tested for dolomite content by the method described by Brenner ('42, p. 104), with results indicating a very high proportion of dolomite crystals. Porosity tests showed about 25 per cent pore space, as compared with values of 3 to 9 per cent for massive dolomite and limestone from the same localities, and 10 to 12 per cent for sandstone.

Soil tests made on the glades at Gray Summit (S.17, T.43N, R.2E) indicated a slight acid reaction and a high organic content. There is very little material corresponding to the leaf litter of the adjacent woods, and the high organic content should probably be ascribed to slow decomposition rather than abundant supply of organic material. This is related to the meager soil flora and fauna, which is in turn due to the extreme variations in temperature and moisture conditions of the glades. It is probable that the amount of available plant nutrients in the glade soil is low, though no attempt has been made to investigate this point.

Probably more important than the chemical composition of either the rock or the soil is the thin-bedding of the dolomite (fig. 5). The beds vary from a fraction to three or four inches in thickness, and contain numerous vertical joints. The presence of bedding planes and joints, along with the extreme porosity of some of the beds, results in ample space for subsurface water. The thin-bedded strata which outcrop in the glades are typically underlain by relatively impermeable massive strata, usually dolomitic, which check the downward percolation of water. This water moves laterally along the numerous bedding planes and, since there is no soil mantle to diffuse it, there is abundant seepage at the outcrops from late autumn to early summer.

Pluvial conditions are also important in the saturation of the glades during the winter and their desiccation during the summer. The mean annual precipitation in this region is about 43 inches. On the whole, the greatest part of this falls during the summer, and the least during the three winter months. At Union, which can be taken as typical of the glade area, since it is only about three miles west of the area included in the map, there are two peaks of

4.54 inches in May and 4.70 in August, and a minimum of 2.20 inches for February. The effective precipitation for the glades, however, presents a somewhat different picture. During the winter and spring months, the rhythmic succession of cyclonic storms brings some sort of precipitation at least once a week. This is usually in the form of a slow drizzle resulting in relatively high infiltration and low run-off, hence much water passes underground. Furthermore, little water is lost by evaporation because of the relatively low temperature and high humidity during such periods of precipitation. This saturation may be an important factor in excluding species of the upland climax from the glades by encouraging winter rotting.

During the summer, on the other hand, precipitation is very irregular and in the form of violent, erratic thunderstorms, separated by longer or shorter periods of drought. During such storms the volume of water falling in a given period is great, runoff is excessive and infiltration is low, hence little water goes underground, particularly on the glades where the soil mantle is thin. The high temperature and low humidity which often follow such thunderstorms further reduce the effective precipitation. Again, the thin soil of the glades contributes to their xeric condition in the summer. A thick layer of soil normally forms a mulch which retards evaporation of subsurface water. The lack of such a mulch on the glades makes for rapid desiccation during warm weather.

The angle of slope of the glades is relatively steep and it appears to be an important factor in determining their characteristics. The slope of a few large glades has been measured by hand-leveling and pacing. There is considerable local variation in gradient at different levels, which can be ascribed to the presence of strata of different resistance, but the average slope appears to vary from 15 to 20 per cent, while that of adjacent north-facing wooded slopes approximates 10 per cent. This steep gradient permits even small volumes of water washing down the slope to carry a considerable load, and is probably one of the principal reasons for the thin soil cover. The steep slope of the glades, coupled with their southern and western attitude, gives them a high angle of incidence to the sun's rays during the warmest part of the day. The attitude of the glades also exposes them to the drying effect of the prevailingly southern winds of the Ozark region.

In the opinion of the writers the dolomitic glades of this area

are permanent ecological entities, entitled to be called an edaphic climax, rather than the first stage in the succession leading to a sugar maple-white oak climax, as they have been regarded by Steyermark ('40, p. 372 et seq.). The fact that open grassland was formerly much more extensive in the Ozarks, and that, with the white settlement of the country and the accompanying reduction of fires, there has been a widespread invasion of the grassland by forest, is too well documented to be doubted. However, the extensive Ozark grasslands of the early nineteenth century occupied hill and ridge tops, where glades rarely occur, and there is no reason for believing that they owed their existence to any more permanent factor than the annual fires which were encouraged by the Indians and early settlers. The dolomitic glades described here, however, seem to present too extreme a set of environmental factors to permit their invasion by trees of the upland climax of this region. The glades seem to be so largely determined by the character of the geological substrate that it would appear to require a rather large-scale change in climatic conditions to obliterate them.

Many of the glades are subjected to grazing by cattle, and to a lesser extent by hogs. Grazing naturally aggravates the barrenness, and occasionally the overgrazing is so severe that practically no plant cover remains. At best the glades produce poor pasture, and a considerable proportion shows no evidence of grazing. It does not seem probable, from a comparison of grazed and apparently ungrazed glades, that they owe their existence to grazing. On the contrary, moderate grazing seems to encourage the appearance of red cedars.

It has been pointed out above that glades occurring on the St. Peter sandstone and on the Plattin and Kimmswick formations differ considerably in character from the dolomitic glades. Barrens are also found on the La Motte sandstone, and in granitic, porphyritic, and highly cherty areas of the Ozarks (Steyermark, '40; Palmer, '10). None of these have been investigated by the present writers, but they should probably all be distinguished from the dolomitic glades of this study.

The glades of this area bear resemblances to the glades and bald knobs of the White River region of Missouri and Arkansas, and to the cedar glades of the Nashville Basin in Tennessee (Harper, '26; Freeman, '33). Relations may also be pointed out between the flora of the glades and that of the Great Plains. The shale barrens

of Virginia and West Virginia (Wherry, '30; Core, '40) appear to represent a similar geologically determined habitat, and they have some floristic similarities to the glades in this area.

Acknowledgments are due the following persons for valuable assistance and criticism: Prof. Edgar Anderson, Prof. L. F. Thomas and Prof. Courtney Werner, of Washington University, Dr. Julian A. Steyermark of the Field Museum of Natural History, Prof. James S. Cullison of the Missouri School of Mines, Mr. H. S. McQueen of the Missouri Geological Survey and Dr. Norman Hinchey, formerly of the Missouri Geological Survey. Mr. McQueen has generously given us access to valuable unpublished maps. The writers are also indebted to the staffs of the Jefferson, Franklin, Washington and Ste. Genevieve County Agricultural Conservation Associations, particularly Mr. Wayne O. Killion of Jefferson County, for their generosity in permitting study of the aerial photographs.

SUMMARY

This paper is a description and analysis of a characteristic type of Ozark vegetation, known locally as "glades," which occur on outcrops of thin-bedded dolomite. A brief enumeration of the flora and a detailed map of these glades for an area in east-central Missouri are presented.

The areal distribution of the glades is determined by geological factors and local relief. Their environmental characteristics, most important of which are winter saturation and summer desiccation, are ascribed to a complex of factors, including thin-bedding of the dolomite, thin soil mantle, steepness of slope, and attitude to the sun's rays.

The glades are regarded as an edaphic climax rather than as a stage in the succession to forest climax.

The relation of the glades to similar vegetational areas elsewhere is discussed.

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